HUMAN FACE DETECTION

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS & COMMUNICATION ENGINEERING

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CERTIFICATE

This is to certify that the work in the thesis entitled ***Human Face Detection*** submitted by ***Sameer Pallav Sahu*** (Roll No. **108EC008**) and ***Pappu Kumar Thakur*** (Roll No. **108EI036**) in fulfilment of the requirements for the award of Bachelor of Technology Degree in Electronics and Communication Engineering at NIT Rourkela is an authentic work carried out by them under my supervision and guidance. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

Date: 14-05-2012

Place: Rourkela

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Professor

Department of Electronics and Communication Engineering

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Contents

List of Figures

List of Tables

ABSTRACT

Face Detection is fast becoming a familiar feature in various technical fields such as video surveillance, military applications, apps and on web, potentially making life easier for us. In current era of social networking Face Detection is a hot topic of research in both academics and commercial area throughout the world. Quite interestingly, the variation in the human skin colour between different races existing in this world primarily is the intensity that is proportional to the amount of melanin in the skin. So our approach towards face detection which uses skin colour seems effective since the skin colour database for various races can easily be collected.

In our project, we have studied and worked on face detection techniques and developed an algorithm that detects human faces in an image. Our algorithm identifies possible skin regions in an image and using the skin colour spread in the whole image detects faces. We have taken our own still images as examples and simulated the algorithm in MATLAB 7.10.0 successfully.

CHAPTER-1 INTRODUCTION

Face is unique property of human beings which is a primary focus of attention in social life playing an important role in conveying identity and emotions. This unique property is quite robust despite large variations in visual stimulus due to changing conditions such as environment, aging and other natural factors (beards, moustache, hairstyles and spectacles).

Human's capabilities are very good at recognizing and remembering faces despite the passage of time. Hence, it's essentially beneficial if the current computer technologies become as robust as humans in face detections.

Face detection is a computer coding technology that determines the locations and sizes of human faces in a given image format. Basically, it detects only the facial features and ignores the rest like trees, building, etc.

Our aim in this project, which we managed to achieve to some extent, was to develop a simple method to detect human faces in a given image which is fast, simple, accurate and can be applies to various races existing throughout the world. In our simulations in MATLAB 7.10.0, the examples shown are real time and images taken from our own digital cameras.

CHAPTER-2 Importance of Face Detection

Face detection is a wide field and there are many ways that face detection technology is changing the way we use and interact with present day technology.

2.1 People Face Tagging

Facebook's automatic tag suggestion feature, which used face detection to suggest people that we might want to tag in our photos, got the public hot under the collar earlier this year. Many may find this feature questionable but it certainly saves time. It's available on various platforms such as Picasa, Facebook, Flickr, etc.

2.2 Face Recognition

Face recognition is a separate vast area which uses face detection consisting of a system which helps in many ways such as enhancement of security by using surveillance cameras in conjunction with face recognition systems, checking for criminal databases, patter recognition, etc.

2.3 Gaming

Face detection is bringing a whole new dimension to gaming. Microsoft's Kinect's advanced motion sensing capabilities have given the Xbox 360 a whole new lease of entertainment and opened up gaming to new audiences by completely doing away with hardware controllers.

2.4 Image Search

Google recently introduced the ability to search images by comparing them to others. By uploading an image or Googling an image Link, it will show you where that image is used on the Internet, and display similar images too. The ability to search for similar images is a boon for photographers searching to check where their images have been used. It’s also great for checking if an image is genuine as it said it was.

2.5 Conservation of Energy

This field is a hot topic of research in current world of energy saving schemes. Face detection systems are installed in almost all high power consuming electronics appliance, be it T.V, refrigerators, smart homes, etc. The face detection system scans 24X7 for a possible face in the given area monitored by the scanners. If it doesn’t finds a face the appliance turns off by itself thereby saving wastage of energy.

2.6 Security Systems

Face detection could one day replace password login as our favourite apps – imagine logging in to Twitter with your face, for example It’s not fooled by photographs, either!

CHAPTER-3 SKIN DETECTION

3.1 Our approach

Face detection is the first step of face recognition; however, it involves many complexities such as postures, lighting, background, etc.

There exists many approaches towards face detection such as colour based, neural networks and feature based techniques. Our approach is skin-color based which is robust, simple and effective.

Our algorithm of face detection system consists of three steps.

- Classification of each pixel in the given image as a skin pixel or a non-skin pixel.
- Identify different skin regions or the skin spread in the skin detected binary image by using connectivity analysis.
- Determine whether each of the skin regions identifies as a face or not. This is done using two parameters i.e. the height to width ratio of the skin detected regions and the percentage of skin in the rectangle confined by the height and width.

3.2 Color Space

A color space is an abstract mathematical model describing the way colors can be represented as tuples of numbers, typically as three as three or four values as color components. A wide range of colors can be created by the primary color of pigment. Those colors then define a specific colorspace. The resulting 3-D space then provides a unique position for every possible color that are possible by combining those three pigments.

3.2.1 RGB

RGB uses additive color mixing, because it describes what kind of light needs to be emitted to produce a given color. RGB stores individual values for red, green and blue. RGBA is RGB with an additional channel, alpha, to indicate transparency.

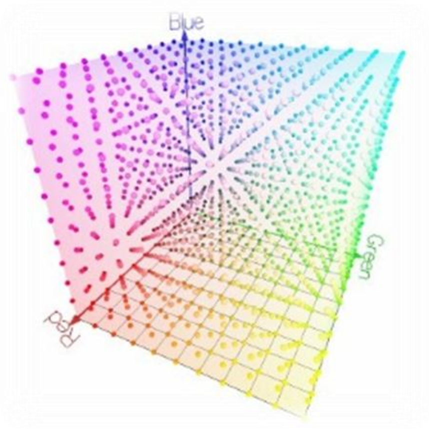

Figure 1 RGB Colorspace

3.2.2 HSV

HSV (hue, saturation, value), also known as HSB (hue, saturation, brightness) is often used for artististical purposes because it is often more ideal to think about a color in terms of hue and saturation than in terms of additive and subtractive color components. HSV is a transformation of an RGB colorspace and its components and colorimetry are proportional to the RGB colorspace from which it was derived.

In the HSV space, H stands for hue component, which describes the shade of the color, S stands for saturation component, which describes pureness of the hue (color) while V stands for value component, which describes the brightness. The removal of V component takes care of varying lighting conditions.

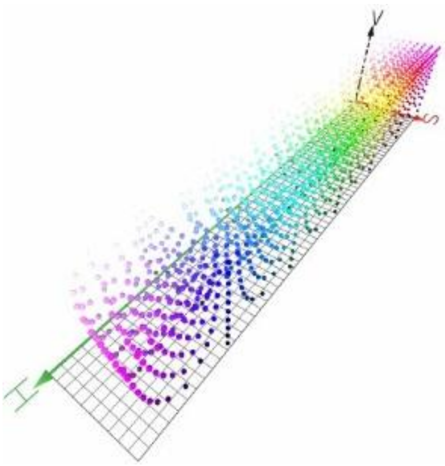

Figure 2 HSV Colorspace

3.2.3 YCbCr

YCbCr is a family of colorspace used as a part of the color image pipeline in digital and video systems. Y is the luma component and CB and CR are the blue-difference and red-difference chroma components. Y′ (with prime) is distinguished from Y which is luminance, which means that light intensity is non-linearly encoded using gamma correction.

YCbCr is not an absolute color space but it is a way of encoding RGB information. The color displayed depends on the actual RGB used to display the signal.

$$Y = 0.299R + 0.587G + 0.144B$$

$$Cb = R - Y$$

$$Cr = B - Y$$

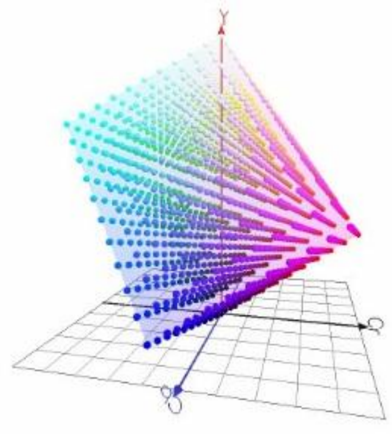

Figure 3 YCbCr Colorspace

3.3 IMAGE RESIZING

The reason why you should resize images if you plan to load images to the Internet for display on a web page or for inserting into a presentation is that image file size matters as memory is limited. On the web, the larger the image size the longer it will take the web page to load. For users who have slower connections, this matters a lot.

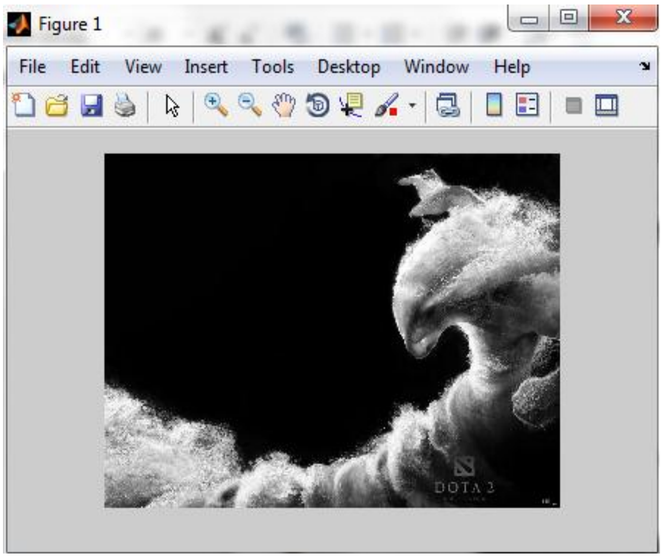

Figure 4 Original input image for image resizing

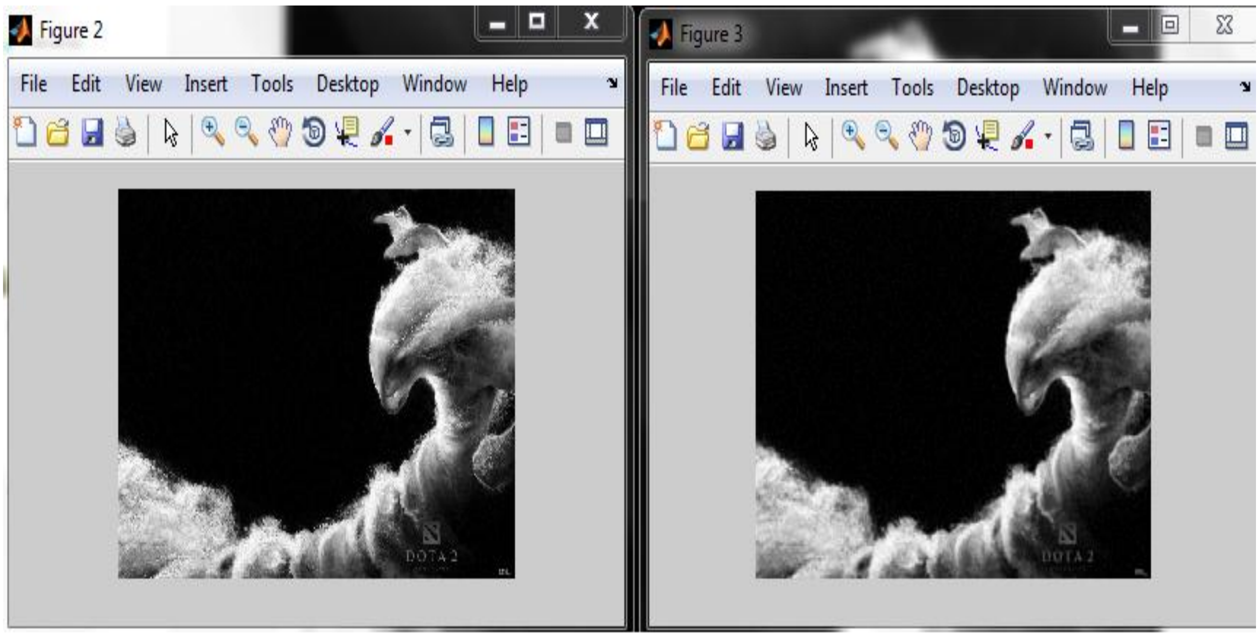

Figure 5 Resized images

3.4 COLOR DETECTION IN AN IMAGE

Color detection in an image is used to detect a particular color spread or the particular color pixel throughout a given image. For instance, separating green component in a given RGB image. This process is beneficial in lot of aspects of image processing. Here, in our project, color segmentation can be used to apply in order to separate skin color form an image by figuring out the skin color values or components.

Figure 3.4(a) acts as an original image taken from a Dota2 hero model-Morphling Figure 3.5(a) contains the unique spectrum. Figure 3.5(b) describes only the green pigments or the green component of the original Dota2-Morphling.

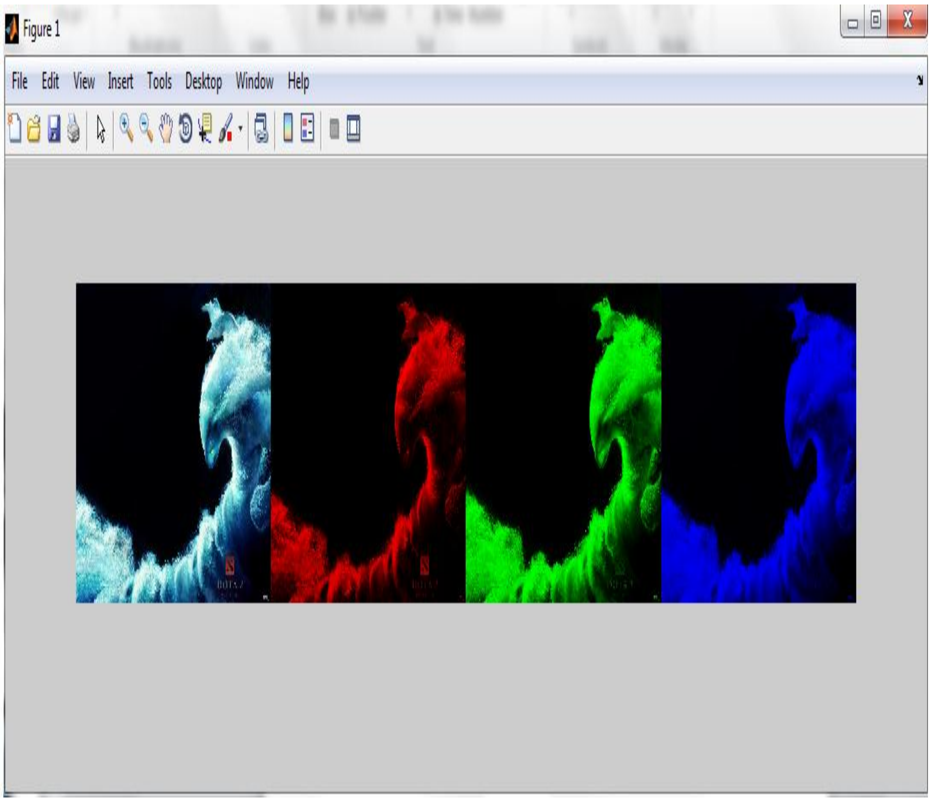

Figure 6 Color separated images

Figure 7 Green components segmented

Hence the concept of color segmentation is essential in our study of skin color segmentation. Similar to the segmentation of rgb components in an image we monitor the values for skin color and apply segmentation technique in order to separate possible skin color from other colors in an image. In our future study we emphasis on skin color segmentation using color segmentation concept wherein we build skin color database and store them via histograms.

3.5 SKIN PIXEL CLASSIFICATION

Different color spaces used in skin detection previously include HSV, normalized RGB, YCbCr, YIQ and CIELAB. However, in our thesis we discuss about basically three most used color space formats i.e. RGB, HSV and YCbCr.

- RGB is developed with CRT as an color space and it has high non-uniformity, correlation and mixing of chrominance and luminance data. Thus RGB is not suitable for color analysis and color based recognition. To solve this problem, normalized RGB has been introduced to obtain the chromaticity information for more accuracy. However, normalized RGB still suffer by uneven illuminations.
- HSV and YCbCr color spaces have the chromaticity and luminance information. The separation of the brightness information from the chromaticity and chrominance in the HSV.
- Compare to HSV, YCbCr is an encoded nonlinear RGB signal and the transformation simplicity and explicit separation of chrominance and luminance components makes this colorspace attractive for skin color modelling.

3.6 SKIN COLOR SEGMENTATION

Skin segmentation aims to locate skin regions in a still input image. It plays an important role in many computer vision areas such as face detection, face tracking, hand segmentation for gesture analysis, and filtering of objectionable Web images. In these tasks, results of skin segmentation enable subsequent detection to focus on reduced skin regions instead of the entire input image. To this very day, skin segmentation is a very effective tool because skin regions can be located fast with usually minimal amount of added computation.

Skin color segmentation can be defined as the process of differentiating between skin and non-skin pixels. However, there are some difficulties in effectively detecting the skin color. The ambient of the light and shadow can affect the appearance of the skin color. Moreover different cameras produce different color values even from the same person and moving object can lead to blurring of colors. Finally, people have varied skin color-tones individually such as Asians skin gives big difference with different skin type.

Most existing skin segmentation approaches are based on skin color. Skin regions are detected by looking for pixels that have skin colors. In this thesis, we propose an algorithm that combines color and edge information to segment skin regions in color images.

Briefly, for skin color segmentation to be done on an image, first a appropriate color space has to be chosen which would prove it easy to implement. From 3.5 skin color classification we come to conclusion that YCbCr colorspace has advantage over RGB and HSV color space.

So we convert the given RGB image to YCbCr. Then we need to define a skin threshold to identify possible skin pixels which is obtained by training data. Training data can be computed from a skin model.

We perform Skin color segmentation using the following 4 steps:

- Converting RGB to YCbCr
- Skin model
- Edge Detection
- Connective analysis

3.6.1 RGB TO YCbCr CONVERSION

YCbCr is not an absolute color space; instead, it is a way of encoding RGB information. The color displayed depends on the actual RGB used to display the signal.

$$Y = 0.299R + 0.587G + 0.144B$$

$$Cb = R - Y$$

$$Cr = B - Y$$

3.6.2 SKIN MODEL

Skin modelling is used to model the distributions of skin and non-skin color pixels in an image. Mainly there are two different approaches are used for skin modelling. Non-parametric methods include normalized lookup table and Bayes classifier are histogram based approach where it estimates the skin color distribution from the computed training data without deriving any explicit model of the skin color. These are methods very effective in piecewise linear decision boundaries.

3.6.2.1 EXPERIMENTAL DATA

A real time experiment was performed by extracting the images of skin from the faces of 20 students (figure 3.6) and their skin pixel values and composition is recorded and studied in order to get Y, Cb, Cr values.

Figure 8 Images for database of Skin Model

3.6.2.2 HISTOGRAM PLOT

The Histogram was plotted for Y (figure 3.7), Cb (figure 3.8), Cr (figure 3.9) values.

The histogram was used to calculate the values of mean and the standard deviation of luminance which were found to be

Mean = 78

Standard Deviation = 31

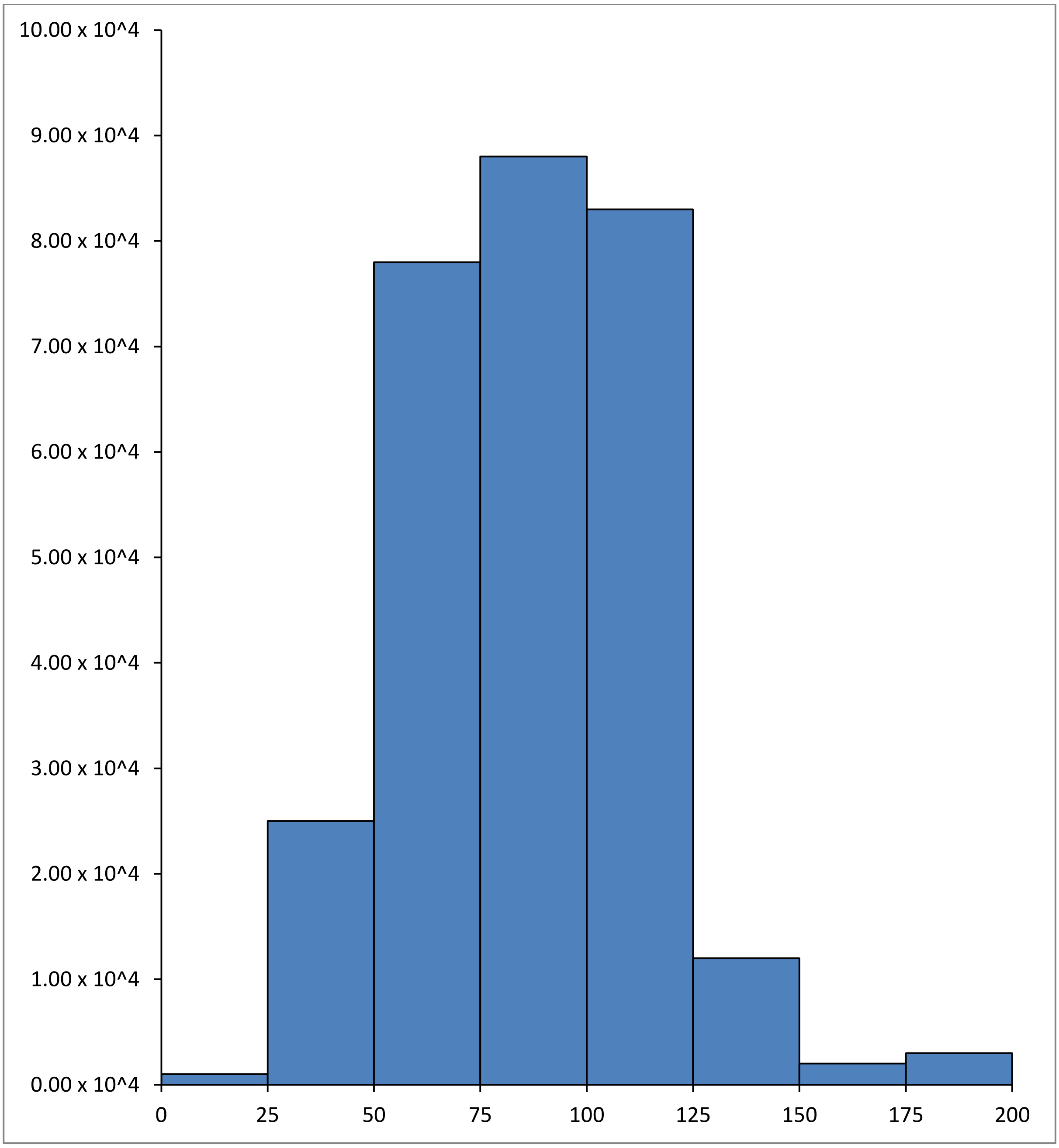

Figure 9 Histogram Plot of Y

Mean = -5.2

Standard Deviation = 9.5

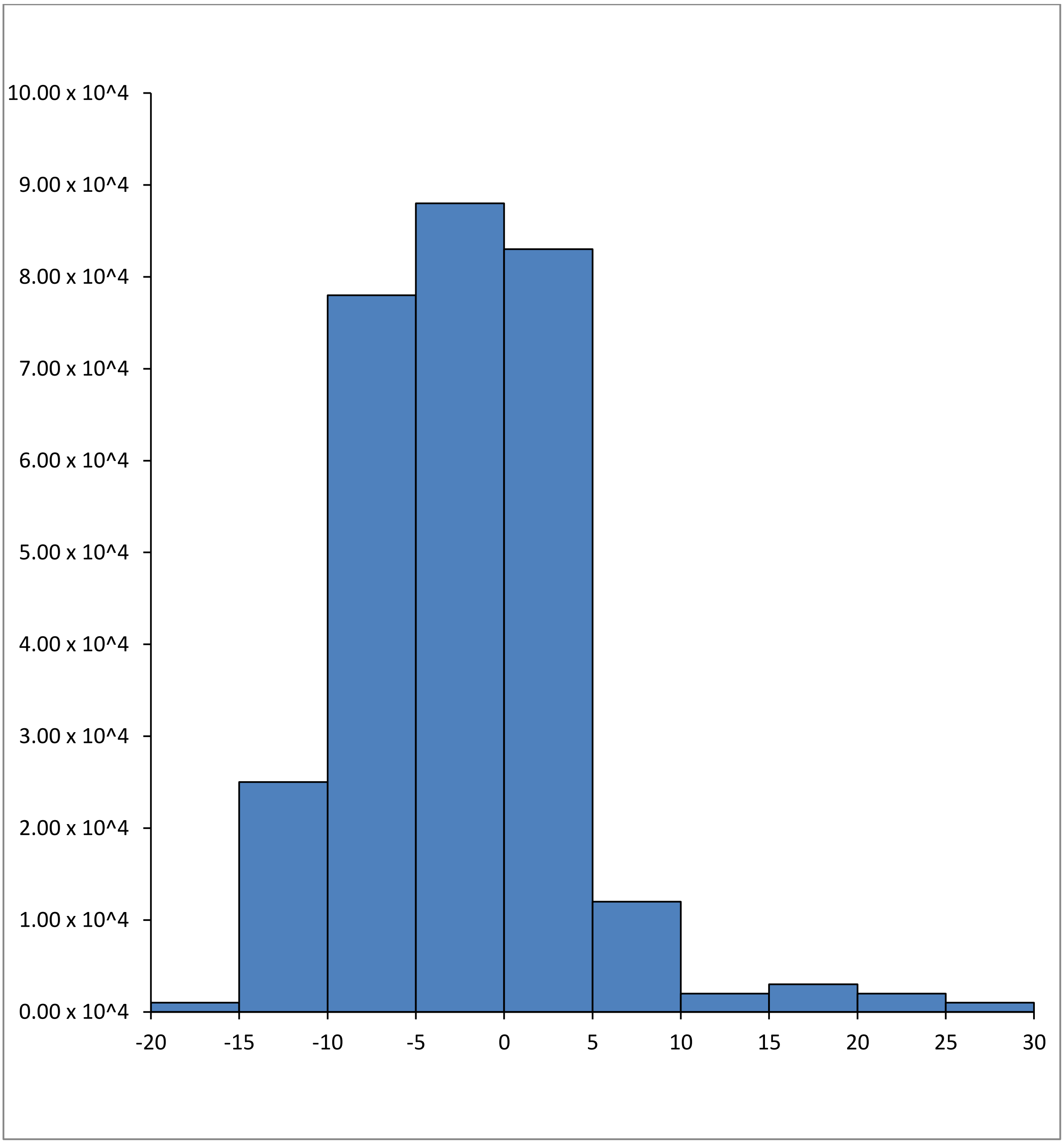

Figure 10 Histogram Plot of Cb

Mean = 6.4

Standard Deviation = 8

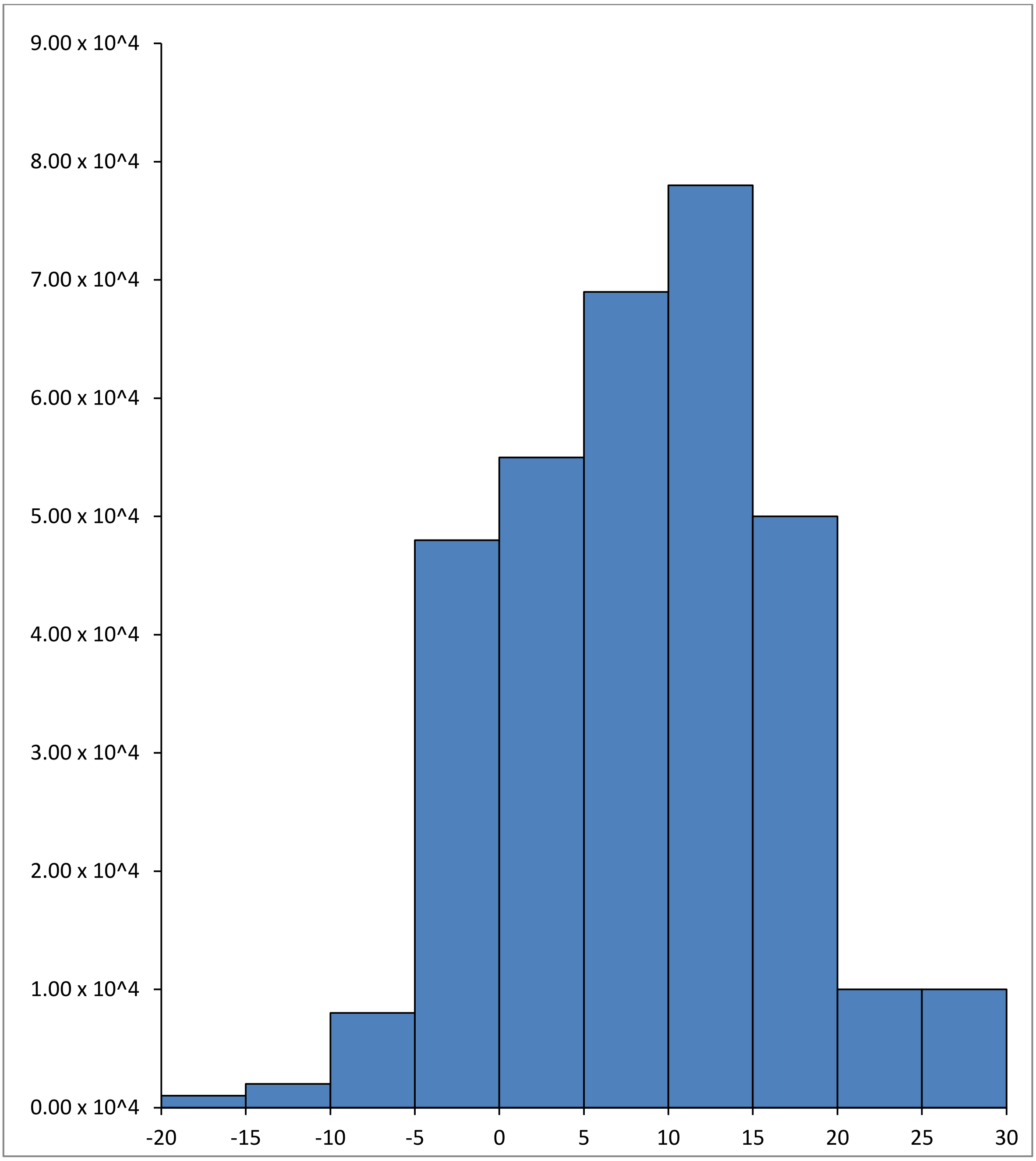

Figure 11 Histogram Plot of Cr

CHAPTER 4 EDGE DETECTION

Edge detection is essential in our project as it detects edges before feeding the input for further processing through skin segmentation to detect skin. There are many operators in MATLAB which helps in edge detection such as Sobel's operator, Prewitt's operator, Robert's operator, etc.

We studied the first three aforementioned operators to detec edges by taking real-time images of ourselves and simulated in MATLAB.

4.1 SOBEL OPERATOR

The Sobel operator is used in digital image processing, particularly for edge detection . Basically, its a discrete differentiation operator and computes an approximation of the opposite of the gradients of the image intensity function. At each point in the image, the results of the Sobel operator is either the corresponding inverse of the gradient vector or the norm of that vector. The Sobel operator is almost based on convolving the image with a small and integer valued filter in vertical and horizontal directions and is therefore relatively easier in terms of computations.

We performed Edge detection using Sobel operator on two different images and the studied the edge detected binary image as output. Figure 3.10(a) and Figure 3.10(b) are the corresponding outputs.

Figure 12 Original input image for edge detection

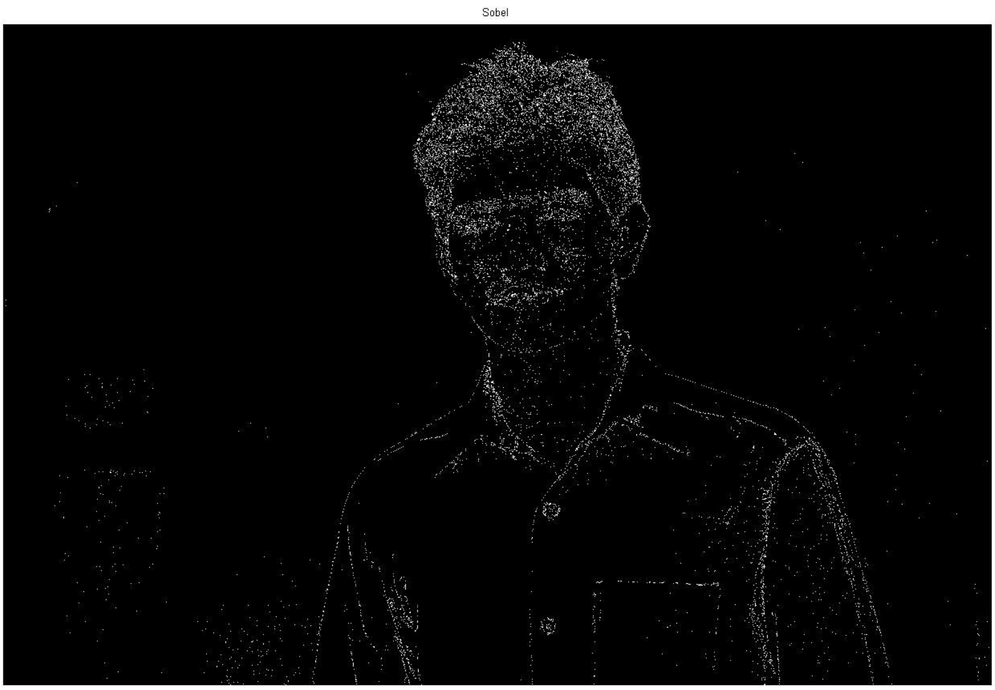

Figure 13 Sobel edge detection for fig 12

This image clearly contains more number of edges as compared to Fig3.10 as this image has many persons in it. Since we need perform our experiment on various conditions, we conducted experiments on two different types of images.

Figure 14 Original image 2 for edge detection

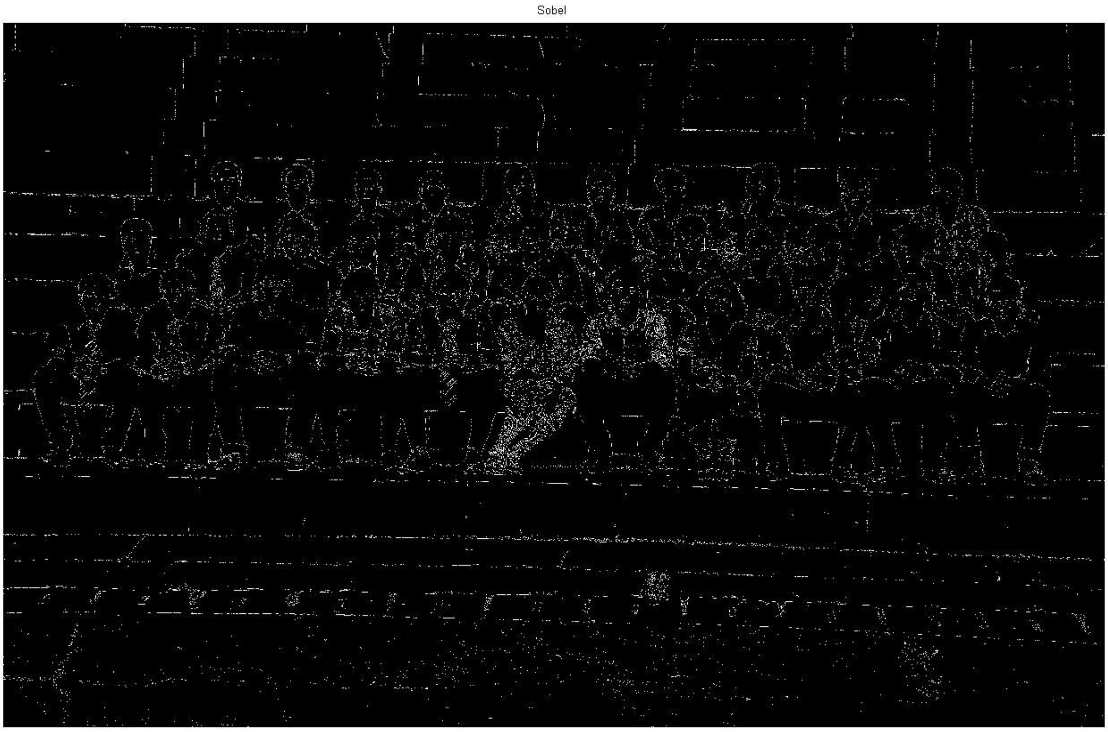

Figure 15 Sobel Edge detection for input image fig 14

4.2 PREWITT OPERATOR

The sole difference between Sobel and Prewitt is the weighting of the middle row-column, vertical and horizontal kernels respectively. Sobel uses a weight of 2/-2 whereas Prewitt uses of 1/-1 resulting in smoothing since more importance to the centre point is given.

We conducted similar experiment as done with sobel operator by taking two different images fig 3.10 and fig 3.12 as original images.

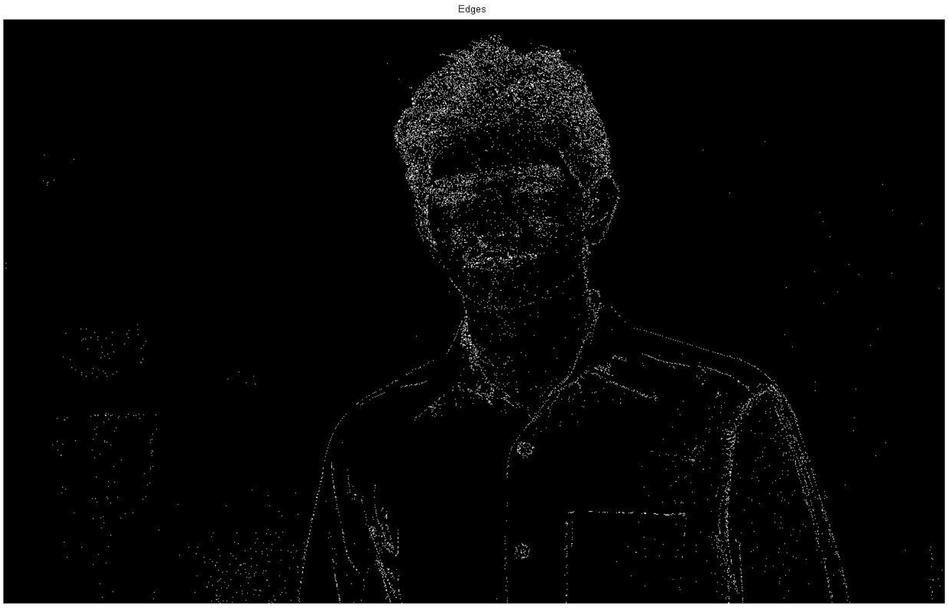

Figure 16 Prewitt edge detection for fig 12

Figure 17 Prewitt edge detection for fig 14

4.3 ROBERT OPERATOR

The Robert cross operator is a simple gradient operator base don 2X2 gradient operator. This Operator the simplest approximation of the gradient magnitude given as

$$G[f(I,j)] = [f(i,j) - f(i+1,j+1)] + [f(i+1,j)- f(I,j+1)]$$

Similar experiment was conducted for Robert operator taking fig 3.10 and fig 3.12 as input images.

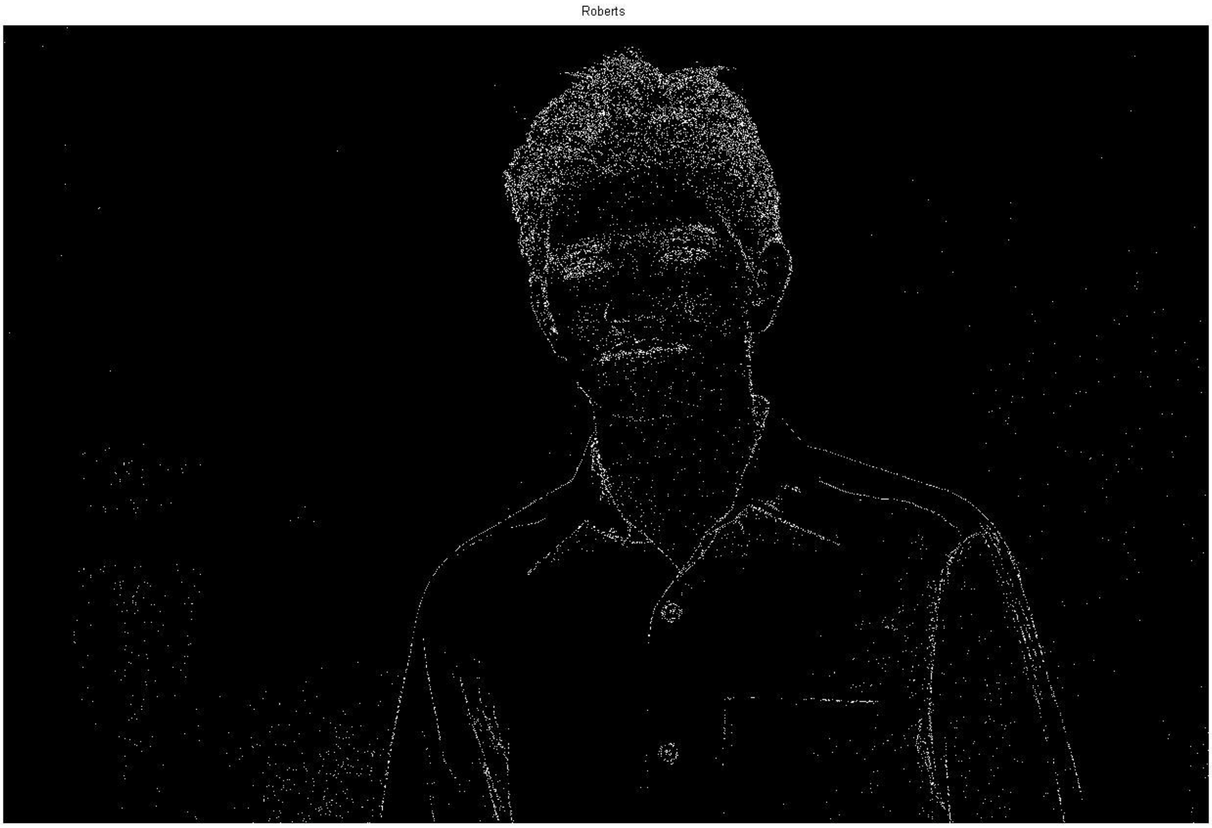

Figure 18 Robert edge detection for fig 12

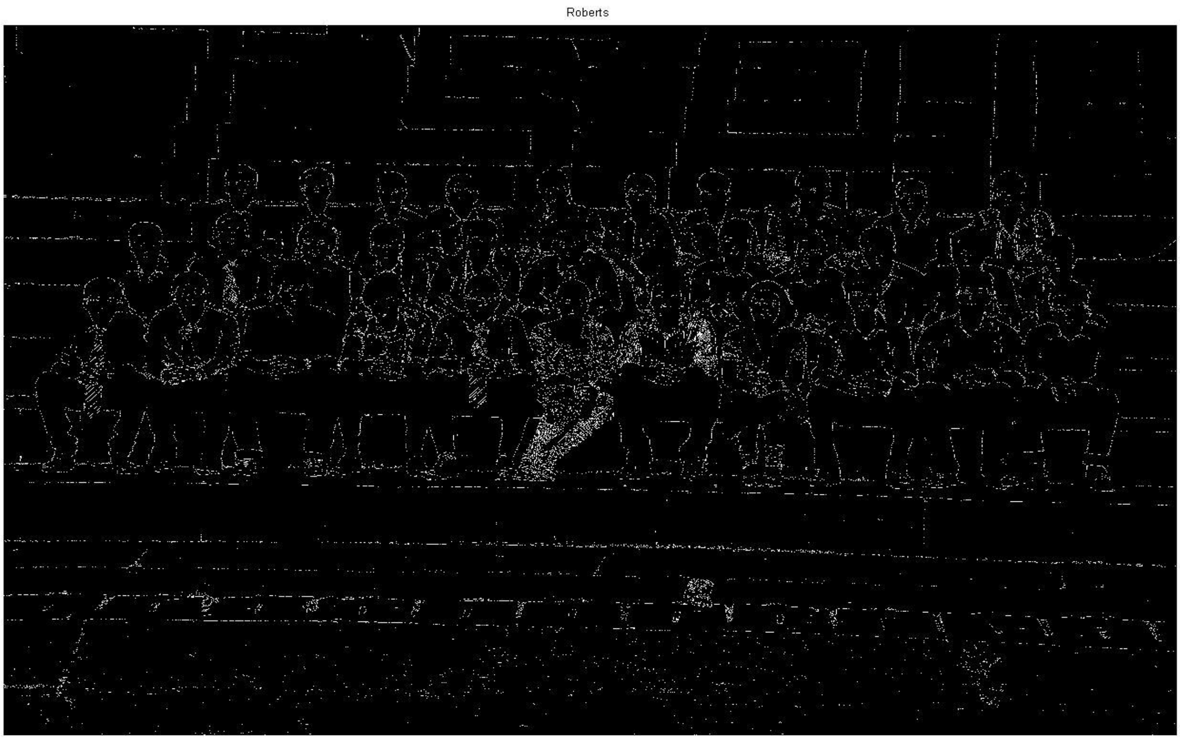

Figure 19 Robert edge detection for fig 14

After our study on the experimental results from all the three edge detecting operators we conclude that Sobel operator is best for MATLAB use as default edge operator is Sobel operator in MATLAB as otherwise all three operators returns almost similar outputs.

After our study we set a function Edge (i,j) which scans for edge in an image. We define an edgethres which stands for edge threshold for determining edges in an image. These user-defined functions come into play later for determining skin pixels.

4.4 DETERMINING SKIN PIXELS

In previous chapters we were able to define a color space for our given image then build a Skin Model from the student skin database and afterwards detect edges in the images by using various edge detecting operators. Now our aim is to determine skin pixel in the image.

We assume a function 'histogram(i,j)' which contains the color space values we got from histogram plot of our Skin Model in YCbCr and a function 'skincolorthreshold(i,j) for the threshold of skin color obtained from skin model. Now when,

Histogram(Cb,Cr)>skincolorthreshold and Edge(i,j)<Edgethres

(i,j) is a skin pixel.

Our basic algorithm so far for determining skin pixel:

- Conversion of RGB image into YCbCr colorspace.
- Corresponding pixel[i,j] values are set to YCbCr values
- If(Histogram(Cb,Cr)>skincolorthreshold && Edge(i,j)<Edgethres)

  then pixel(i,j) is a skin pixel.

CHAPTER 5 SKIN COLOR SEGMENTATION

5.1 CONNECTIVE ANALYSIS

In the previous chapters we studied and experimented on getting skin detected images from a given input jpg image. Now we need to define specific regions of skin in order to use the image for further processing in face detection algorithm. In connective analysis grouping of skin pixels in the image based on 8-connected neighbour.

5.2 MATLAB SIMULATIONS

Skin color segmentation is performed on various images of different conditions and the results are studied. For example, skin color segmentation was conducted on the fig 3.10 and fig 5.3 as input image.

We computed two kinds of experiments. First we set a threshold to skin pixels in a range where skin likelihood of each pixel had maximum value of 5.92 and minimum value of -12.88. Then a binary skin map was computed which was much easier to work with since the function used in binary skin map is that value is 0 if it is not a skin pixel and 1 if it is a skin pixel. Two different types of images were taken for this purpose. One with one face only and the other with multiple faces.

Figure 20 Original image1 for skin color segmentation

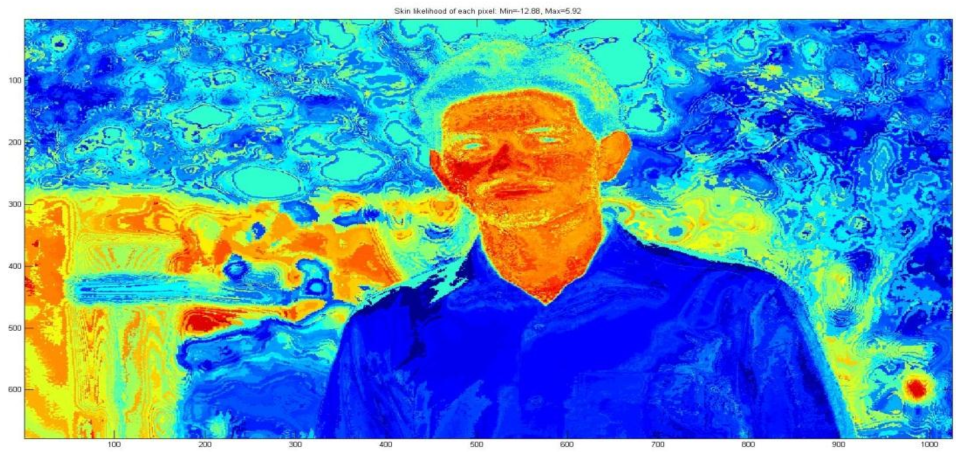

Figure 21 Skin likelihood image of fig 20

Figure 22 Binary skin image of fig 20

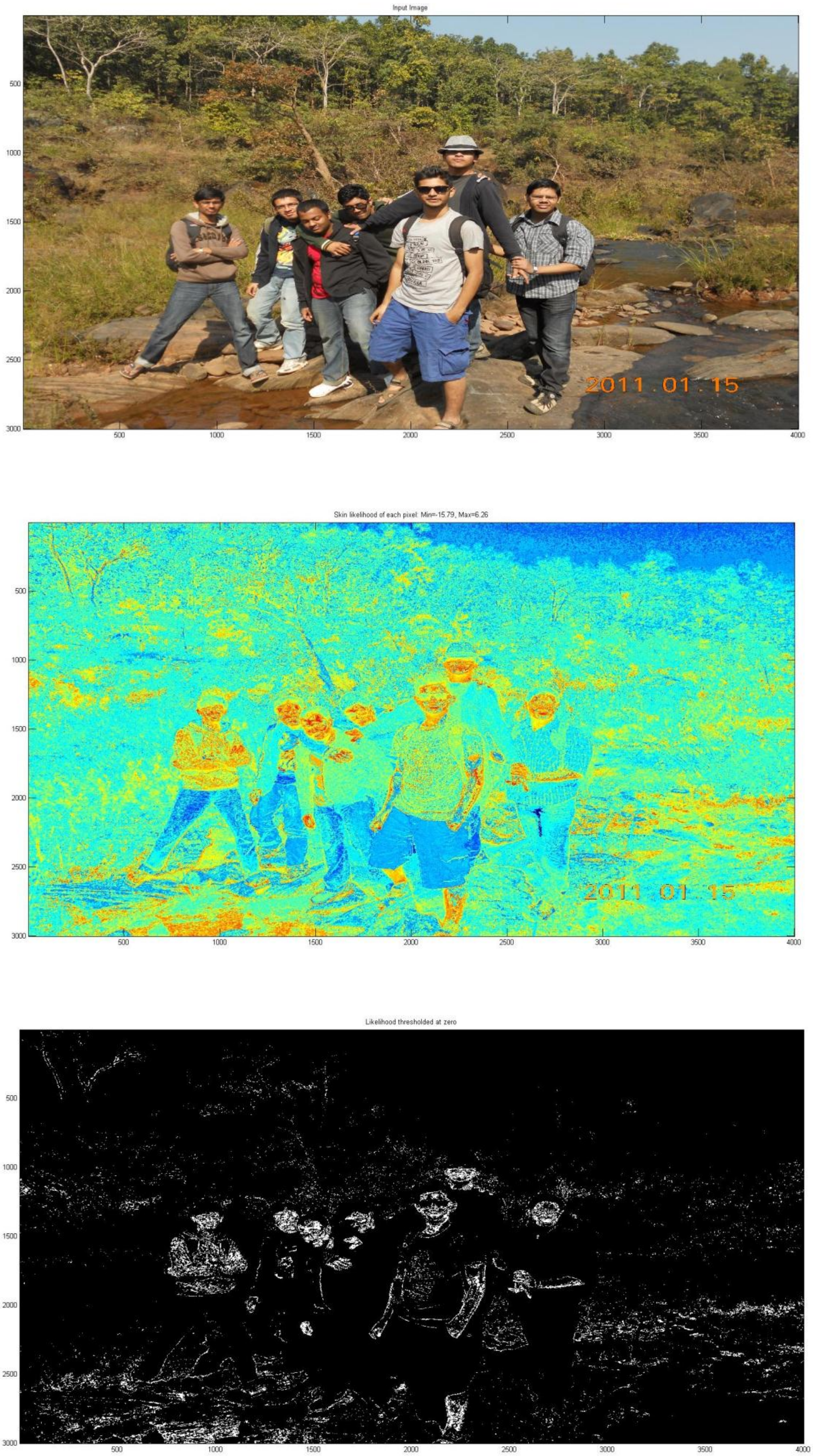

Figure 23 Skin color segmentation

CHAPTER 6 FACE DETECTION

6.1 ALGORITHM

The algorithm used for face detection in our project

- Conversion of RGB image into YCbCr colorspace.
- Corresponding pixel[i,j] values are set to YCbCr values
- If(Histogram(Cb,Cr)>skincolorthreshold && Edge(i,j)<Edgethres) then pixel(I,j) is a skin pixel
- Find the regions in the image by applying connective analysis using 8-connected neighbour
- Find height, width and centroid of the regions and percentage of skin in that particular region
- If height and width is within the well-defined range and (percentage of skin) > (Percentage threshold) then region is face else it is not.

Similar to the prior experiments, real-time data in the form of our own images were taken and face detection procedure was performed on them. The results were studied and errors were noted. To check the flexibility of our algorithm different types of images were taken as inputs and were simulated in MATLAB for face detection.

A single face image was taken and simulated in MATLAB and the errors were noted down. The whole process was recorded fig 6.1.

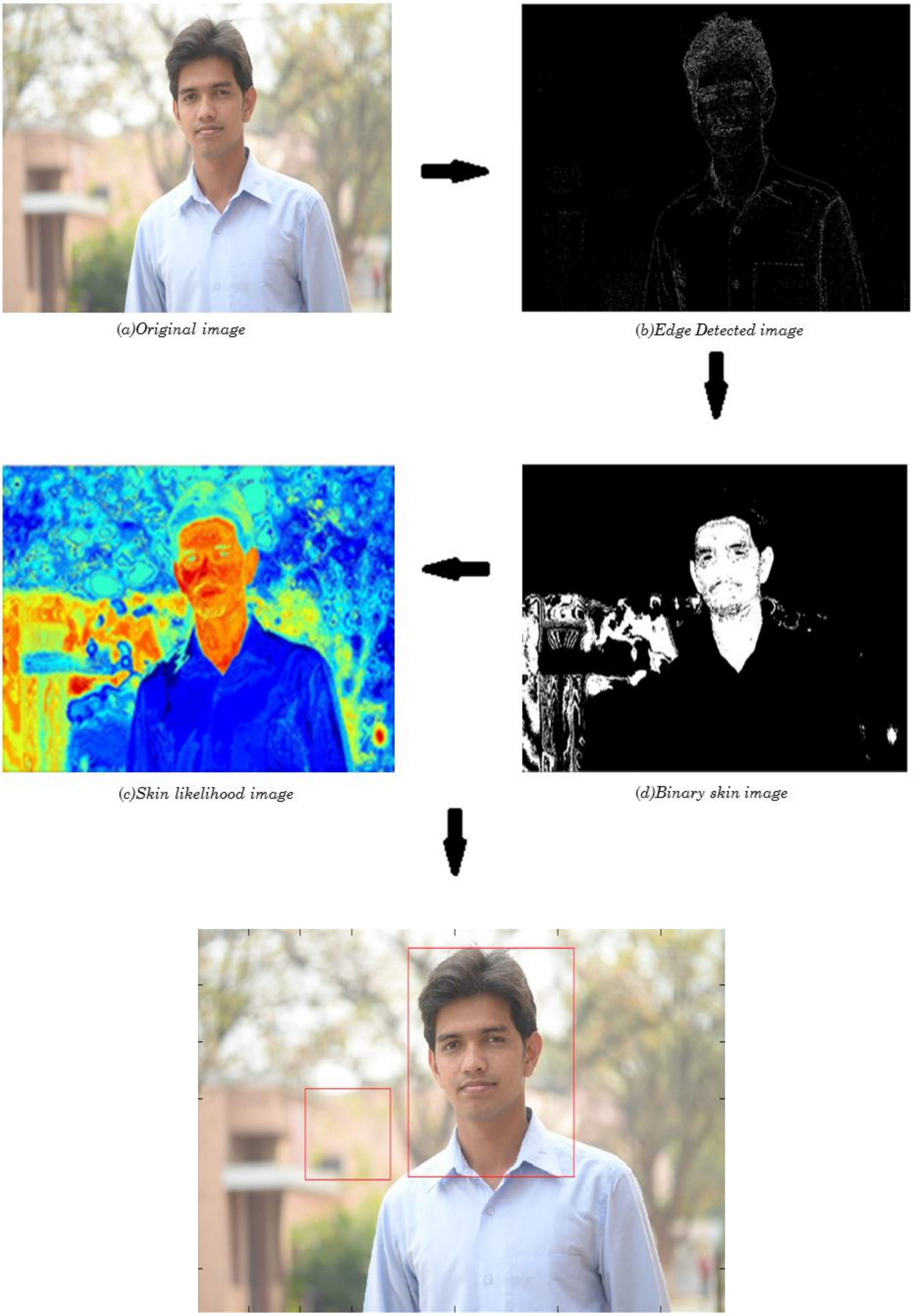

Figure 24 Face Detection simulation on single face image

Next we take an image which contains multiple faces and apply our algorithm by simulating the image in MATLAB.

Figure 25 Multiple faces Original image for face detection

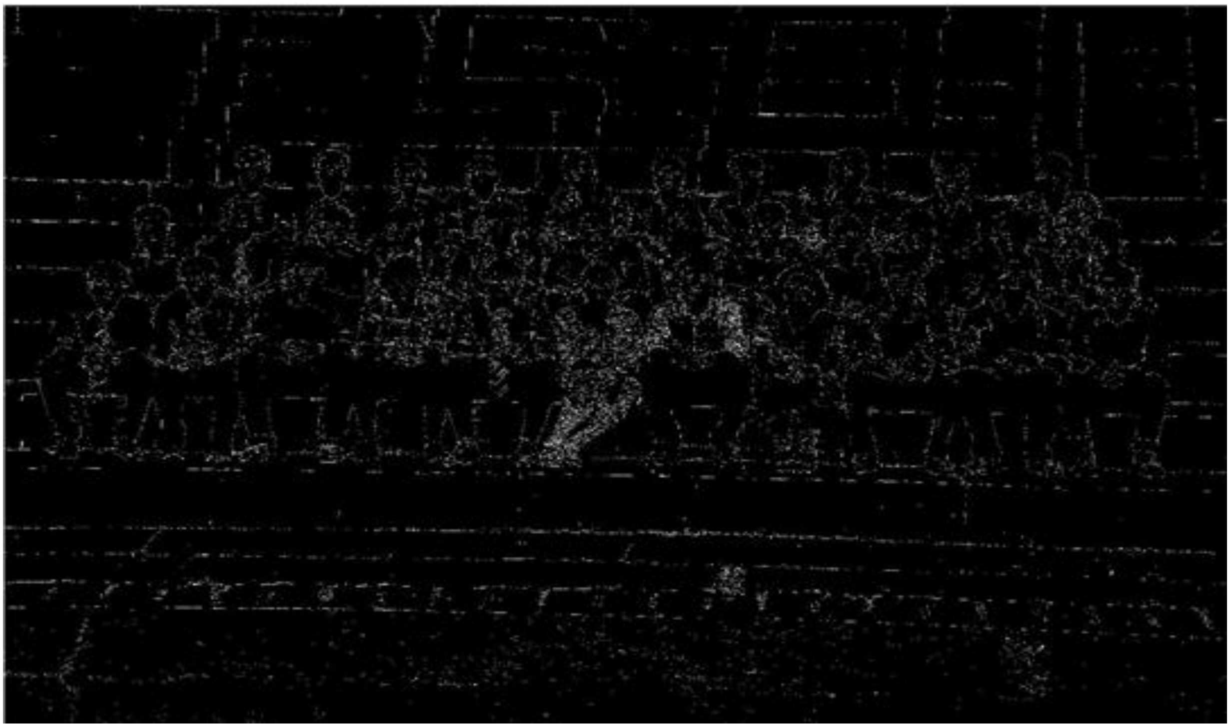

Figure 26 Edge detected image of fig 25

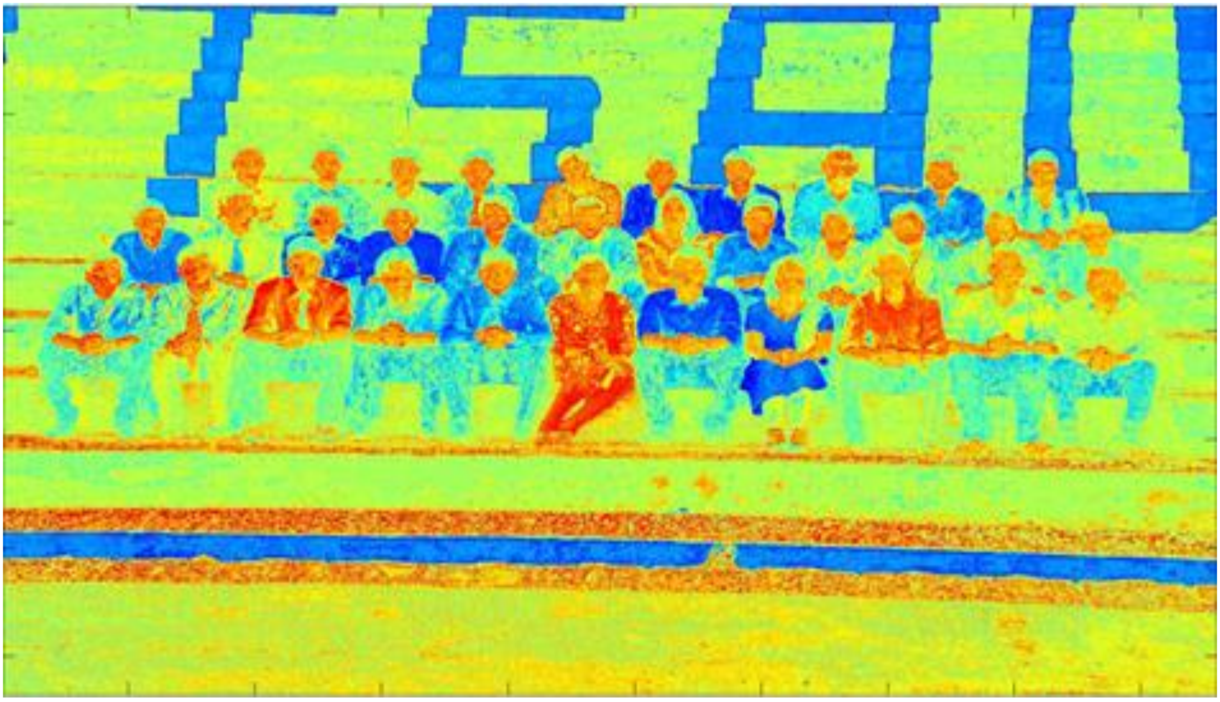

Figure 27 Skin likelihood image of fig 25

Figure 28 Binary skin image of fig 25

Figure 29 Face detected image of fig 25

Since the above example has very less surrounding factors to affect the skin regions so we have perfect face detection in this case.

Our Face detection success so far was recorded in a table:

Table 1 Recorded output I

Serial No.	Resolution	No. of faces	No. of boxes	No. of false detection	Not detected
Fig 24	1024X556	1	2	1	0
Fig 29	1024X556	33	33	0	0

Figure 30 Complex background input image

Figure 31 Edge detected image of fig 30

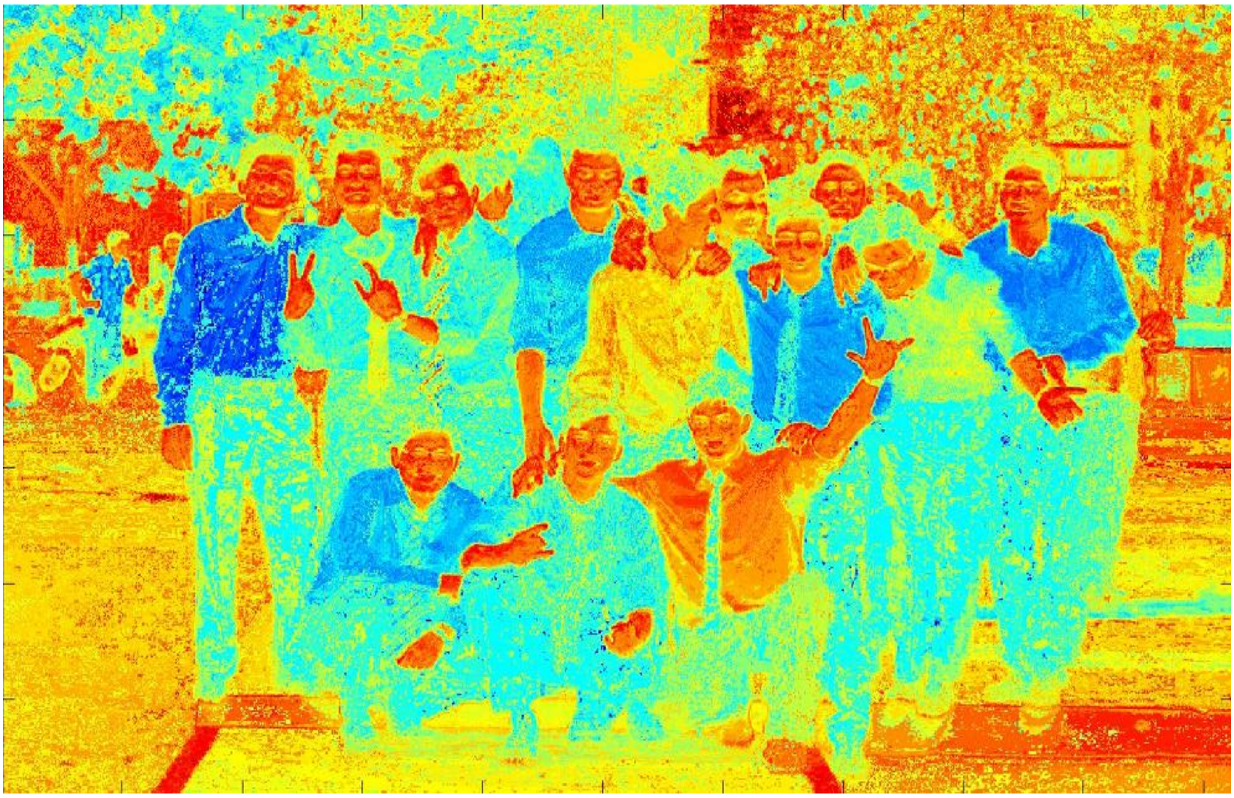
Figure 32 Skin likelihood image of fig 30


Figure 33 Binary skin image of fig 30

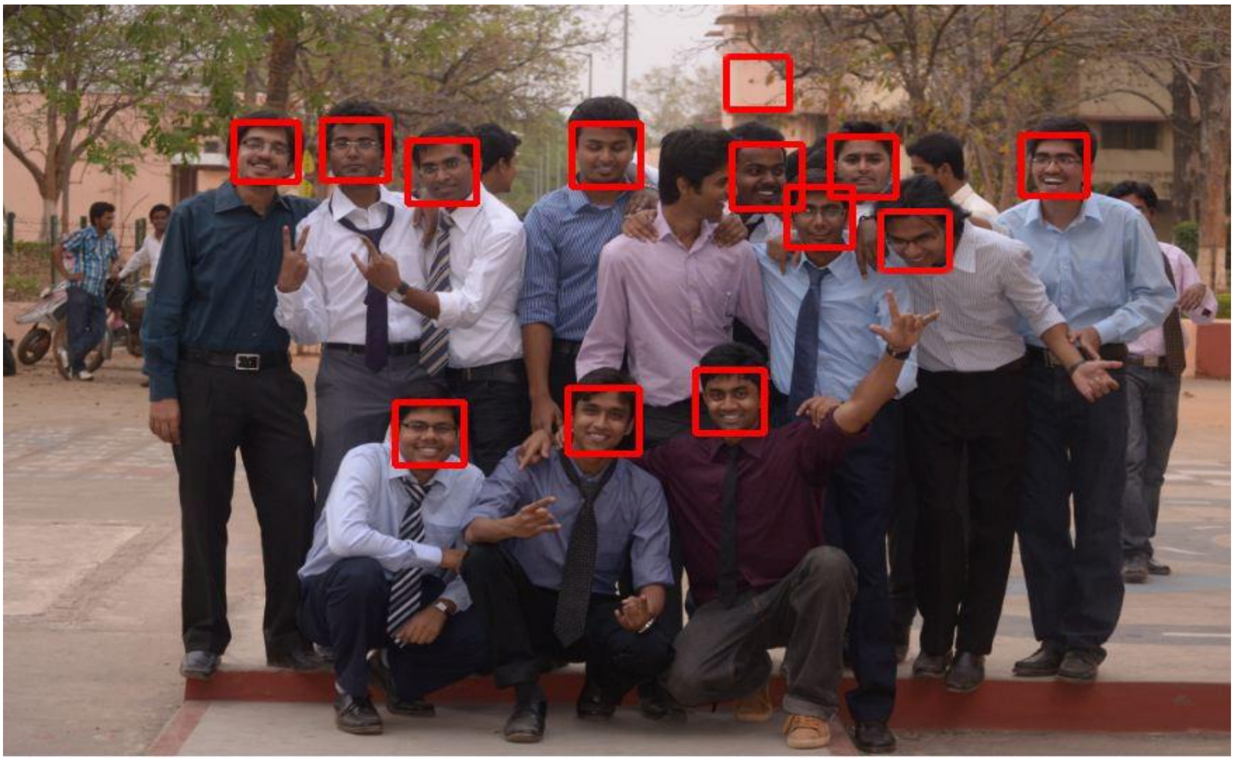

Figure 34 Face detected image of fig 30

Table 2 Recorded output 2

Serial No.	Resolution	No. of faces	No. of boxes	No. of false detection	Not detected
Fig 24	1024X556	1	2	1	0
Fig 29	1024X556	33	33	0	0
Fig 34	1024X556	15	13	1	2

In Fig 6.4 we encountered an error due to the interference of colors in the surroundings. In our next experiment we try to minimise such errors by manipulating with the environments conditions.

The hue and saturation is changed for the background of the images with possible skin color regions.

Figure 35 Modified background input image

Figure 36 Face detected image of fig 35

Similarly changing the background hue and saturation of Fig 6.2 we get the corrected face detected image as follows.

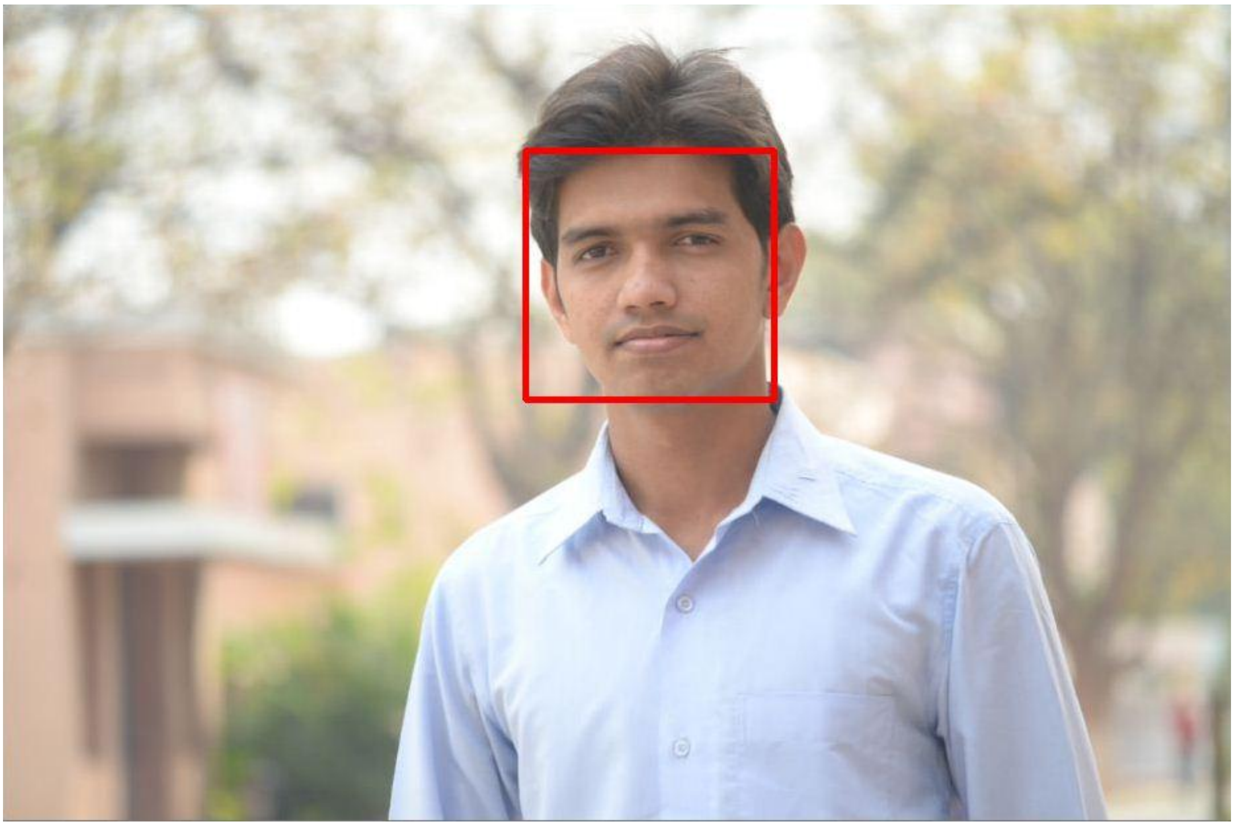

Figure 37 Corrected face detection for fig 20

Table 3 Recorded output 3

Serial No.	Resolution	No. of faces	No. of boxes	No. of false detection	Not detected	Success Rate
Fig 24	1024X556	1	2	1	0	50%
Fig 29	1024X556	33	33	0	0	100%
Fig 34	1024X556	15	13	1	2	80%
Fig 36	1024X556	15	12	0	2	86%
Fig 37	1024X556	1	1	0	0	100%

CONCLUSION

The face detection algorithm were thoroughly studied and put to practical use by simulations in MATLAB 7.10.0. Simulations were done on various images under different conditions and the error and success rates were recorded. The success rate was different for different images depending on the external factors. The overall success rate was found to be 95.33%.

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